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(54) METHODE DE GRILLAGE DU MINERAI D'OR REFRACTAIRE
(54) PROCESS OF ROASTING REFRACTORY GOLD ORES

(57)
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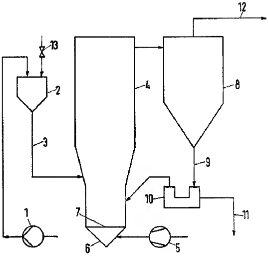

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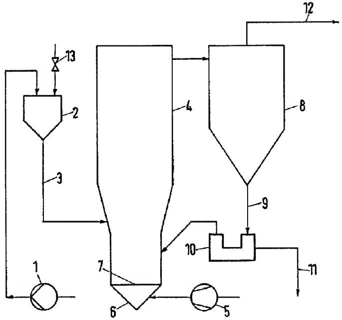

(57) Abrégé/Abstract:
Refractory gold ores are roasted by means of oxygen-containing gases in a circulating fluidized bed at temperatures of 500 to 750°C. The temperature in the lower portion of the fluidized bed contained in the reactor is adjusted to be 4 to 30°C higher than the temperature in the upper portion of the fluidized bed. The fluidizing gas is caused to floor into the reactor at a velocity of 30 to 200 m/sec.

ABSTRACT

Refractory gold ores are roasted by means of oxygen-containing gases in a circulating fluidized bed at temperatures of 500 to 750°C. The temperature in the lower portion of the fluidized bed contained in the reactor is adjusted to be 4 to 30°C higher than the temperature in the upper portion of the fluidized bed. The fluidizing gas is caused to flow into the reactor at a velocity of 30 to 200 m/sec.

The present invention relates to a process of roasting refractory gold ores by means of oxygen-containing gases in a fluidized bed.

Refractory gold ores are ores which cannot directly be leached with NaCN and which as gold-bearing substances contain pyrites, arsenopyrites or pyrites associated with more or less organic carbon. In the processing of such materials the leaching with cyanide must be preceded by an oxidation of the contents of sulfur and carbon to the highest possible degree. That oxidation has been effected in the past mainly by roasting. But sulfuric acid must be produced to remove of the SO_2, which is formed by the roasting, from the roaster exhaust gas. In many cases, however, the site of the mine is so unfavorable that the sulfuric acid which is produced is rather a ballast. Besides, the roasting resulted in a clogging of part of the pores of the particles by recrystallized iron oxides so that the yield of gold was decreased.

For this reason the oxidation has increasingly been effected more recently by other processes, such as pressure oxidation in an autoclave, bacterial leaching or

oxidation by nitric acid or chlorine. The dicisive difference from roasting resides in that in said processes the sulfur is directly produced as sulfuric acid and/or iron sulfate and must be neutralized with $CaCO_3$ and CaO before the leaching with cyanide. Part of said processes are much more expensive than roasting.

"Journal of the South African Institute of Mining and Metallurgy", Vol. 86, No. 5, May 1986, discloses on pages 157 to 160 that flotation concentrates of gold-containing pyrites can be roasted or pyrolyzed in a fluidized bed. The pyrolysis is effected in a fluidized bed which is operated with nitrogen as a fluidizing gas and which is heated to 700 to 800°C by electric resistance heating. The reactor comprises two concentric tubes. The material is charged into the annular space and subsides therein and is then raised in the inner tube and in part falls back into the outer annular space. The sulfur which has been distilled off is condensed. But the final product of the pyrolysis consists only of FeS. Besides, expensive electric power is required to produce the heat required for the reaction.

German Patent Specification 26 24 302 discloses that sulfide ores or ore concentrates can be roasted at temperatures between 450 and 1200°C in a circulating fluidized bed system, which is fed with oxygen-containing fluidizing gases. Solids are removed from the reactor of the circulating

fluidized bed system and are cooled in a separate fluidized bed cooler. Part of the cooled solids are recycled to the reactor. The heated fluidizing air from the fluidized bed cooler is fed as secondary air to the reactor. Information on the roasting of refractory gold ores has not been furnished in connection with that process.

It is an object of the invention to provide for the roasting of refractory gold ores a process which will result in an optimum product for the leaching with cyanides and in which the production of sulfuric acid can be omitted if this is necessary.

In accordance with the present invention, that object is achieved with a process of roasting refractory gold ores by means of oxygen-containing gases in fluidized bed having an upper portion and a lower portion, the process comprising the steps of;

- roasting the gold ores in a circulating fluidized bed system at temperatures from 500 to 750°C, the fluidized bed system comprising a fluidized bed reactor containing the fluidized bed;

- adjusting the temperature in the lower portion of the fluidized bed to be 4 to 30°C higher than the temperature in the upper portion of the fluidized bed, and

- causing the fluidizing gas to flow into the reactor at a velocity of 30 to 200 m/sec.

According to a preferable aspect of the invention a method is proposed for roasting refractory gold ore in a fluidized bed which is located in a fluidized bed reactor above a perforated bottom which has numerous gas passage

openings, the fluidized bed having a lower part and an upper part, wherein air or air enriched with oxygen is passed upwards through the perforated bottom into the fluidized bed as fluidizing gas, the gold ore is roasted in the fluidized bed at temperatures of 500 - 750°C and solids-containing exhaust gas withdrawn from the reactor is passed through a cyclone to separate off solids, the method is characterized in that the roasting of the gold ore is effected in a circulating fluidized bed, with the solids concentration within the reactor constantly decreasing from bottom to top, that the solids-containing exhaust gas is passed from the reactor into the cyclone and the solids separated off in the cyclone are returned to the fluidized bed reactor in a quantity per hour which corresponds to at least 5 times the weight of the solids contained in the reactor, that the gold ore to be roasted is introduced into the fluidized bed at least 1 m above the perforated bottom, that the temperature in the lower part of the fluidized bed is set to 4 to 30°C higher than in the upper part of the fluidized bed and that the fluidizing gas emerges from the openings of the perforated bottom into the fluidized bed at velocities of 30 to 200 m/sec.

The refractory gold ores which may be used may consist of ores or of concentrate. The oxygen-containing gases which may be used may consist of air or of oxygen-enriched air. The circulating fluidized bed system preferably consists of the fluidized bed reactor, the recycle cyclone, and the recycle line for recycling the solids collected in the recycle cyclone. The term "recycle cyclone" is applicable to one

recycle cyclone or to a plurality of recycling cyclones having gas paths connected in parallel. From an "orthodox" fluidized bed, in which a dense phase is separated by a distinct density step from the overlying gas space, the fluidized bed used in accordance with the invention differs in that the fluidized bed reactor contains states of distribution having no defined boundary layer. There is no density step between a dense phase and an overlying dust space, and the solids concentration decreases gradually in the reactor from bottom to top. The following regions will be obtained if the operating conditions are defined by the Froude and Archimedes numbers

$$0.1 \leq 3/4 \cdot Fr^2 \cdot \frac{\rho g}{\rho k - \rho g} \leq 10 ,$$

and

$$0.01 \leq Ar \leq 100 ,$$

wherein

$$Ar = \frac{d_k^3 \cdot g (\rho k - \rho g)}{\rho g \cdot \nu^2}$$

and

$$Fr^2 = \frac{u^2}{g \cdot d_k}$$

and

u = the relative gas velocity in m/sec

Ar = the Archimedes number

Fr = the Froude number

ρ_g = the density of the gas in kg/m^3

ρ_k = the density of the solid particles in kg/m^3

d_k = the diameter of the spherical particles in m

ν = the kinematic viscosity in m^2/sec

g = the constant of gravitation in m/sec^2

The suspension discharged from the fluidized bed reactor is fed to the recycle cyclone of the circulating fluidized bed system and substantially all solids are collected from said suspension in the recycle cyclone and are recycled to the fluidized bed reactor in such a manner that the weight of solids circulated per hour in the circulating fluidized bed system is at least five times the weight of the solids contained in the fluidized bed reactor. The temperature in the fluidized bed reactor is adjusted to a constant value within the stated range but the temperature in the lower portion of the fluidized bed is higher by the stated amount than the temperature in the upper portion of the fluidized bed. The higher temperature in the lower region of the fluidized bed is achieved in that the ore is fed on a level which is spaced a predetermined distance of at least 1 meter above the bottom so that an atmosphere which is richer in oxygen is maintained below the feeding level and Fe_3O_4 is oxidized to Fe_2O_3 in said atmosphere. The Fe_2O_3 enters the upper portion of the fluidized bed, where the atmosphere is poorer in oxygen, and is partly reduced there to Fe_3O_4 and is then returned to the lower portion, where it is reoxidized. The oxidation of Fe_3O_4 to Fe_2O_3 supplies part of the heat which is required in the process. The oxygen content of the fed gas is adjusted to a value which is close to the stoichiometric value related to the

sulfur and carbon contents of the material. The temperature difference between the lower and upper portions of the fluidized bed is a reliable measure of the ratio of Fe_2O_3 to Fe_3O_4 in the calcine which is discharged. The optimum ratio of magnetite to hematite for the leaching with cyanide will be achieved by a selection of the prooer temperature difference in the reactor for the feed material used. The temperature difference will be controlled by the oxygen content of the fed gases. The velocity of 30 to 200 m/sec of the fluidizing gas is the velocity at which the fluidizing gas exits from the openings of the perforate bottom into the reactor. If the ore has a low calrific value, the fluidizing gas or a partial stream of the fluidizing gas can be preheated by an indirect heat exchange. That preheating may be effected by the exhaust gas from the circulating fluidized bed system or by the discharged solids. If the ore has a low calorific value, a directly preheated secondary gas may be fed to the reactor above the perforate bottom and the preheating may be effected in a separate fluidized bed cooler, which contains an orthodox fluidized bed. The hot calcine is discharged into that fluidized bed cooler and is cooled therein with oxygen-containing fluidizing gas. The oxygen-containing fluidizing gas which has thus been heated is fed as secondary gas to the reactor of the circulating fluidized bed system. The fluidized bed cooler may also contain cooling surfaces,

through which the fluidizing gas for the circulating fluidized bed is passed and is thus preheated. If the circulating fluidized bed system is fed with a concentrate which has relatively high contents of sulfur and/or carbon, it will be necessary to dissipate heat from the fluidized bed. That dissipation of heat may be effected by cooling surfaces in the fluidized bed reactor or by a cooler for a circulated stream. That cooler for a circulated stream is a separate fluidized bed cooler, which contains a stationary fluidized bed and is fed with the solids collected in the recycle cyclone or part of said solids and is also fed with oxygen-containing gases as a fluidizing gas. The fluidized bed contains cooling registers, which are flown through, e.g., by water. The cooled solids or part of the cooled solids are recycled to the reactor of the circulating fluidized bed system. The heated fluidizing gas may be fed as a secondary gas to the fluidized bed reactor of the circulating fluidized bed system. The dissipation of heat or a dissipation of part of the heat to be dissipated may also be effected in that the concentrate is fed as an aqueour suspension to the fluidized bed reactor. The exit of the fluidizing gas at the stated velocity will mainly result in the lower portion of the fluidizing reactor in a certain grinding action on the recirculated coarse solids. That grinding action will tear open the partly dense covering layers of iron oxide on the surface of the particles

and in the outer portion of the pores of the particles and will result in an excellent leachability. At the same time the particle size is reduced from, e.g., 50% < 35 µm to 65% < 35 µm.

According to a preferred feature the temperature in the lower portion of the fluidized bed in the reactor is adjested to be 4 to 12°C higher than the temperature in the upper portion of the fluidized bed. A oarticularly good ratio of Fe_3O_4 to Fe_2O_3 in the discharged calcine will be achieved by the adjustment of a temperature in that range.

According to a preferred feature the fluidizing gas is caused to flow into the reactor at a velocity of 50 to 100 m/sec. A good grinding action will be achieved at a relatively low expenditure by the use of a velocity in that range.

According to a preferred feature a sulfur-binding material is fed to the reactor at such a rate that a predominant part of the sulfur content of the gold ore will be bound. The sulfur-binding material which may be used may consist of Ca-containing materials, such as limestone, CaO, and dolomite. Part of the desulfurizing agent may alternatively be contained in the gangue of the ore. The SO_2 which has been formed is bound by the sulfur-binding material mainly as a sulfate and/or sulfite of calcium; the prooortion of sulfite will be low. If it is desired to bind most of the SO_2 by the Ca-containing material and to achieve a good

leachability, the temperature will be preferably be maintained in the range from 650 to 750°C and particularly in the range from 650 to 700°C. Those temperature ranges are the optimum ranges for achieving a binding of the SO_2 and as well as a good leachability of the calcine. Part of the heat required for the reaction is also produced by the production of sulfate.

According to a preferred feature the sulfur-binding material is fed at a rate which is in excess of the rate that is required for binding the sulfur and most of the surplus is reacted to form CaO. In this manner the CaO required for adjusting the pH value for the leaching with cyanide can be produced in a desirable manner so that substantially less CaO or no CaO needs to be added for adjusting the pH value for the subsequent leaching with cyanide.

According to a preferred feature, additional fuel is fed to the fluidized bed. Solid, gaseous or liquid fuels may be fed to the fluidized bed. This will permit an economical roasting also of gold ores which do not contain sulfur and/or coarbon in the amount required for the production of the heat which is required.

According to a preferred feature, sulfur-binding material before being fed to the reactor of the circulating fluidized bed is calcined in a separate fluidized bed and the resulting calcine is fed in a hot state to the reactor.

The separate fluidized bed may be constituted also by a circulating fluidized bed or by an orthodox fluidized bed. That feature will be particularly desirable if low-cost natural gas is available, whch owing to its high ignition temperature of at least 670°C and its low degree of combustion at the relatively low roasting temperatures cannot be used in the circulating fluidized bed. In such case part or all of the CaO which is required for binding the SO_2 and/or for adjusting the pH value is produced in the separate fluidized bed by calcination at, e.g., 950°C with the aid of natural gas and is fed at an elevated temperature to the reactor of the circulating fluidized bed system. As a result, the entire heat of sulfatization of the CaO will additionally be available for the roasting; that heat will usually be sufficient for an autothermic roasting process. In the bombination which is optimum as regards thermal energy, a decomposition of $CaCO_3$ is effected in such a manner in the separate fluidized bed and in the circulating fluidized bed for roasting that the rate at which $CaCO_3$ is decomposed in the separate fluidized bed is just sufficient to maintain an autothermic roasting in the circulating fluidized bed used for roasting.

The invention will be described more in detail with reference to an example and a drawing.

According to Figure 1 a metering pump 1 feeds the material to be processed into the distributor pot 2. The

concentrate suspension is uniformly fed through downcomers 3 into the lower portion of the reactor 4 of the circulating fluidized bed system. Atmospheric air as an oxidizing and fluidizing gas is fed by the fan 5 into the windbox 6 associated with the reactor 4 and flows from there through the perforate bottom 7. The suspension of oxidized solids (calcine) and roaster exhaust gas is discharged from the reactor 4 and is fed to the recycle cyclone 8 of the circulating fluidized bed system. Substantially all solids are removed from said suspension in said cyclone and are recycled to the reactor 4 through the recycle line 9 and the fluidized seal pot 10. Calcine is continuously withdrawn from the fluidized seal pot 10 through the discharge line 11. The dust-laden roaster exhaust gas which leaves the recycle cyclone 8 is fed in the gas line 12 to means for cooling, dedusting and further processing. The flow control valve 13 is used for a supply of water at a metered rate to the concentrate slurry to be fed. The reactor 4 has a height of 25 m above the perforate bottom 7 and the downcomers 3 effect a feeding on a level which is 4 meters above said bottom.

EXAMPLE

A refractory pyrite ore concentrate is used, which contains 40 g gold per 1000 kg and 33.3% sulfide sulfur, which is present as pyrite. The particle size amounts to d_{50} = 30 µm and 100% 200 µm. In an aqueous slurry containing 70% solids, concentrate at a rate of 24,000 kg/h is fed

into the reactor 4 through the downcomers 3. Air at a temperature of 60°C is fed under a pressure of 1.2 bars at a rate of 37,000 sm³/h (sm³ = standard cubic meter) into the windbox 6. The air flows at a velocity of 60 m/sec through the openings of the perforate bottom 7. The temperature amounts to 650°C in the lower portion of the reactor and to 642°C in its upper portion. The rate at which air is fed is controlled to effect a near-stoichiometric combustion. The oxygen content in the upper portion of the reactor is 0.5%. In the calcine discharged through the discharge line 11 the ration of Fe_2O_3 to Fe_3O_4 equals 4:1. The content of sulfide sulfur is 0.2%. A gold yield of 95% is achieved in the further processing. The roaster exhaust gas in line 12 contais 14.8% SO_2 and < 0.5% oxygen.

The advantages afforded by the invention reside in that a formation of covering layers of iron oxide on the particles will substantially be avoided owing to the grinding action. Besides, an optimum ratio of Fe_3O_4 to Fe_2O_3 in the calcine can exactly be achieved and sulfur and carbon are substantially completely combusted so that the resulting calcine has very good leaching properties. Fluctuations in the chemical compositon of the ores can be detected immediately and the pregiven temperature difference in the reactor can be re-established by a correction of the rate at which oxygen is injected. By an addition of sulfur-binding agents the SO_2 content of the exhaust gas can be decreased to such low values that a succeeding plant for producing sulfuric acid will not be required.

CLAIMS

1. A process of roasting refractory gold ores by means of oxygen-containing gases in fluidized bed having an upper portion and a lower portion, the process comprising the steps of;

- roasting the gold ores in a circulating fluidized bed system at temperatures from 500 to 750°C, the fluidized bed system comprising a fluidized bed reactor containing the fluidized bed;

- adjusting the temperature in the lower portion of the fluidized bed to be 4 to 30°C higher than the temperature in the upper portion of the fluidized bed, and

- causing the fluidizing gas to flow into the reactor at a velocity of 30 to 200 m/sec.

2. A process according to claim 1, characterized in that the temperature in the lower portion of the fluidized bed is adjusted to be 4 to 12°C higher than the temperature in the upper portion of the fluidized bed.

3. A process according to claim 1 or 2, characterized in that the fluidizing gas is caused to flow into the reactor at a velocity of 50 to 100 m/sec.

4. A process according to claim 1, 2 or 3, characterized in that a sulfur-binding material is fed to the reactor at such a rate that a predominant part of the sulfur content of the gold ore is bound.

5. A process according to claim 4, characterized in that the sulfur-binding material is fed at a rate which is in excess of the rate that is required for binding the sulfur, thereby providing an excess of sulfur-binding material which reacts to form CaO.

6. A process according to any one of claims 1 to 5, charactetized in that additional fuel is fed to the fluidized bed.

7. A process according to any one of claims 4 to 6, characterized in that sulfur-binding material before being fed to the reactor of the circulating fluidized bed is calcined in a separate fluidized bed and the resulting calcine is fed in a hot state to the reactor.

8. A method for roasting refractory gold ore in a fluidized bed which is located in a fluidized bed reactor above a perforated bottom which has numerous gas passage openings, the fluidized bed having a lower part and an upper part, wherein air or air enriched with oxygen is passed upwards through the perforated bottom into the fluidized bed as fluidizing gas, the gold ore is roasted in the fluidized bed at temperatures of 500 - 750°C and solids-containing exhaust gas withdrawn from the reactor is passed through a cyclone to separate off solids, characterized in that the roasting of the gold ore is effected in a circulating fluidized bed, with the solids concentration within the reactor constantly decreasing from bottom to top, that the solid-containing exhaust gas is passed from the reactor into the cyclone and solids separated off in the cyclone are returned to the fluidized

bed reactor in a quantity per hour which corresponds to at least 5 times the weight of the solids contained in the reactor, that the gold ore to be roasted is introduced into the fluidized bed at least 1 m above the perforated bottom, that the temperature in the lower part of the fluidized bed is set to 4 to 30°C higher than in the upper part of the fluidized bed and that the fluidizing gas emerges from the openings of the perforated bottom into the fluidized bed at velocities of 30 to 200 m/sec.

9. A method according to claim 8, characterized in that a sulphur-binding material is added to the reactor and the quantity is set such that the sulphur content of the gold ore is predominantly bound.

10. A method according to one of claims 8 or 9, characterized in that additional fuel is introduced into the fluidized bed.

11. A method according to claim 9, characterized in that the sulphur-binding material is calcined in a separate fluidized bed before being used in the reactor and the calcined product is passed into the reactor in the hot state.

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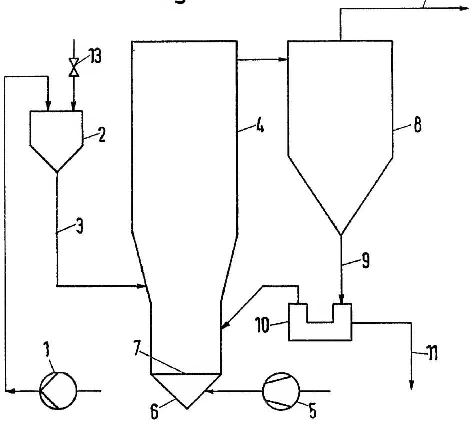
Fig.1



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